



Docket No. NE304-US

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Application of:

Tomohiro SAKAI

Serial No.: 10/652,482

Group Art Unit: 2113

Filed: September 2, 2003

Examiner: Michael C. Maskulinski

For: METHOD AND SYSTEM FOR ANALYZING LOOP INTERFACE FAILURE

Honorable Commissioner of Patents  
Alexandria, VA 22313-1450

**SUBMISSION OF VERIFIED ENGLISH TRANSLATION  
OF THE PRIORITY DOCUMENT**

Sir:

Submitted herewith is a copy of the verified English translation of the Specification, Claims and Abstract, and the Declaration of Isamu Takahashi dated December 22, 2006, that the English translation is a true English translation of the Japanese Application Number 2002-257545 filed September 3, 2002, upon which application the claim for priority is based.

Approval and acknowledgment of receipt are respectfully requested.

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**TRANSLATOR'S DECLARATION**



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10-7, Higashi Kanda 1-chome, Chiyoda-ku, Tokyo 101-0031 JAPAN, do  
hereby declare that I am the translator of the priority document of  
Japanese Patent Application No. JP2002-257545 and swear that the  
following is a true translation to the best of my knowledge and belief.**

**Dated this 22nd day of December, 2006**

A handwritten signature in black ink, which appears to read "Isamu Takahashi". The signature is written in a cursive style and is positioned above a horizontal line.

**Isamu TAKAHASHI**



## **JAPAN PATENT OFFICE**

**This is to certify that the annexed is a true copy of the following  
application as filed with this office**

**Date of Application: September 3, 2002**

**Application Number: JP2002-257545**

**Applicant(s): NEC Corporation**

**July 9, 2003**

**Commissioner,  
Japan Patent Office**

**Shinichiro Ohta**

**Certification Number: Pat. 2003-3055323**

**2002-257545**

<b>[Document Title]</b>	<b>Patent Application</b>
<b>[Control Number]</b>	<b>67000090</b>
<b>[Date of Application]</b>	<b>September 3, 2002</b>
<b>[Direction]</b>	<b>Commissioner, Japan Patent Office</b>
<b>[IPC]</b>	<b>G06F 13/00</b>
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<b>[Account Number]</b>	<b>009715</b>
<b>[Amount]</b>	<b>21,000 yen</b>
<b>[Annex]</b>	
<b>[Title]</b>	<b>Specification   1</b>
<b>[Title]</b>	<b>Drawings       1</b>
<b>[Title]</b>	<b>Abstract        1</b>
<b>[Power of Attorney Number]</b>	<b>9002136</b>
<b>[Proof]</b>	<b>Required</b>

[Document Title] Specification

[Title of the Invention] Method and System for Analyzing  
Loop Interface Failure

[What Is Claim Is]

[Claim 1] A method for analyzing a loop interface failure for a system having multiplexed loop interfaces, in which controlling devices, for controlling loop connection switching means which connect/detach devices to the  
5 respective loop interfaces, are connected to the respective loop interfaces, and interfaces are provided so that the controlling devices communicate each other, comprising a step of, when the controlling devices detect that abnormalities occur in all loop interfaces, controlling the  
10 loop connection switching means so as to detach all devices connected to at least one of the loop interfaces.

[Claim 2] The method for analyzing a loop interface failure as claimed in claim 1, wherein the controlling devices, when detecting that receptions of commands have ceased, which commands are transmitted at a regular  
5 interval through loop interfaces to which the device itself connects, inform via the interface to another controlling devices that the receptions of the commands have ceased, and when detecting that receptions of commands have ceased in all controlling devices, detect that abnormalities occur

10 in all of the loop interfaces.

[Claim 3] The method for analyzing a loop interface failure as claimed in claim 1, further comprising a step of performing a loop diagnosis for identifying a faulty device by accessing to the devices connected to another loop  
5 interface via the devices connected to the loop interface, in which all of the devices were detached from the loop interface so that the loop abnormality has been resolved.

[Claim 4] The method for analyzing a loop interface failure as claimed in claim 3, wherein when abnormalities occur in all multiplexed loop interfaces, a controller, connecting to the devices and to the controlling device  
5 through one loop interface of the multiplexed loop interfaces, judges whether the loop abnormality of the loop interface to which the controller connects is resolved within a certain period of time, and when the loop abnormality was resolved within the certain period of time,  
10 inquires the controlling device whether it detached all devices, and if all devices were detached by the controlling device, performs countermeasure processing against a double-loop link failure, which includes the loop diagnosis by a loop diagnostic means.

[Claim 5] The method for analyzing a loop interface failure as claimed in claim 4, wherein the certain period of time is so set as a little longer than a period of time necessary for the controlling device to detach all of the  
5 devices when the loop abnormalities occur in all of the multiplexed loop interfaces.

[Claim 6] The method for analyzing a loop interface failure as claimed in any one of claims 3 to 5, wherein:  
a device determined as faulty in the loop diagnosis is detached from the loop interface; and  
5 the loop interface is to be in use again.

[Claim 7] The method for analyzing a loop interface failure as claimed in claim 6, wherein the loop diagnosis for identifying a faulty device is performed by accessing to controlling device connected to another loop interface  
5 via the controlling device connected to the loop interface which is in use again.

[Claim 8] The method for analyzing a loop interface failure as claimed in any one of claims 1 to 7, wherein the loop interface is a fibre Channel Arbitrated Loop (FC-AL).

[Claim 9] The method for analyzing a loop interface

failure as claimed in any one of claims 1 to 7, wherein:

the devices are hard disk devices; and

the controlling devices are enclosure service devices.

5

[Claim 10] A system for analyzing a loop interface failure, comprising multiplexed loop interfaces, in which controlling devices, for controlling loop connection switching means which connect/detach devices to the  
5 respective loop interfaces, are connected to the respective loop interfaces, wherein: interfaces are provided so that the controlling devices communicate each other; and when the controlling devices detect that abnormalities occur in all loop interfaces, the controlling devices control the  
10 loop connection switching means so as to detach all devices connected to at least one of the loop interfaces.

[Claim 11] The system for analyzing a loop interface failure as claimed in claim 10, wherein the controlling devices, when detecting that receptions of commands have ceased, which commands are transmitted at a regular  
5 interval through loop interfaces to which the device itself connects, inform via the interface to another controlling devices that the receptions of the commands have ceased, and when detecting that receptions of commands have ceased in all controlling devices, detect that abnormalities occur



10 in all of the loop interfaces.

[Claim 12] The system for analyzing a loop interface failure as claimed in claim 10, comprising a loop diagnostic means for performing a loop diagnosis to identify a faulty device by accessing to the controlling  
5 devices connected to another loop interface via the controlling devices connected to the loop interface in which all connected devices were detached so that the loop abnormality has been resolved.

[Claim 13] The system for analyzing a loop interface failure as claimed in claim 12, comprising a controller connected to the devices and the controlling devices via one loop interface of multiplexed loop interfaces, wherein  
5 the controller, when the loop abnormalities occur in all of the multiplexed loop interfaces, judges whether or not the loop abnormality in the loop interface to which the controller is connected is resolved in a certain period of time, and when the loop abnormality was resolved within the  
10 certain period of time, inquires the controlling device whether it detached all devices, and if all devices were detached by the controlling device, performs countermeasure processing against a double-loop link failure, which includes the loop diagnosis by a loop diagnostic means.

15

[Claim 14] The system for analyzing a loop interface failure as claimed in claim 13, wherein the certain period of time is so set as a little longer than a period of time necessary for the controlling device to detach all of the  
5 devices when the loop abnormalities occur in all of the multiplexed loop interfaces.

[Claim 15] The system for analyzing a loop interface failure as claimed in any one of claims 12 to 14, wherein the loop diagnostic means detaches the devices determined as faulty in the loop diagnosis from the loop interface,  
5 and the loop interface is to be in use again.

[Claim 16] The system for analyzing a loop interface failure as claimed in claim 15, wherein the loop diagnostic means performs the loop diagnosis for identifying a faulty device by accessing to controlling device connected to  
5 another loop interface via the controlling device connected to the loop interface which is in use again.

[Claim 17] The system for analyzing a loop interface failure as claimed in any one of claims 10 to 16, wherein the loop interface is a fibre Channel Arbitrated Loop (FC-AL).

[Claim 18] The system for analyzing a loop interface failure as claimed in any one of claims 10 to 16, wherein:  
the devices are hard disk devices; and  
the controlling devices are enclosure service devices.

[Claim 19] An enclosure service device which is connected to one loop interface of multiplexed loop interfaces and having a function of controlling a loop connection switching means for connecting/detaching devices  
5 to/from the loop interfaces, comprising:

an interface for communicating with another enclosure service device connecting to another loop interface each other; and

a means for controlling the loop connection  
10 switching means when detecting abnormalities in all loop interfaces so as to detach all devices connecting to the loop interface.

[Claim 20] The enclosure service device as claimed in claim 19, comprising a means for detecting that commands, which commands are transmitted at a regular interval through the loop interface to which the device itself  
5 connects have ceased, and informing to other enclosure service devices through the interfaces that the commands

have ceased,, wherein when all enclosure service devices detect that the commands have ceased, the enclosure service device detects that abnormalities occur in all of the loop  
10 interfaces.

[Claim 21] The enclosure service device as claimed in claims 19 or 20, wherein the loop interface is a fibre Channel Arbitrated Loop (FC-AL).

[Claim 22] The enclosure service device as claimed in claims 19 or 20, wherein the devices are hard disk devices.

[Claim 23] A controller connected to one or more devices and to a controlling device having a function of controlling a loop connection switching means for connecting/detaching the devices to/from the loop interface,  
5 via one loop interface of multiplexed loop interfaces, comprising:

a means for confirming that all devices connecting to at least one of the loop interfaces have been detached by the controlling device which detected that abnormalities  
10 occurred in all of the multiplexed loop interfaces; and

a loop diagnostic means for performing a loop diagnosis to identify a faulty device by accessing to a

controlling device connecting to another loop interface  
through the interface connecting the controlling devices so  
15 as to communicate each other, via the controlling device  
connecting to the loop interface in which all devices were  
detached and the loop abnormality has been resolved.

[Claim 24] The controller as claimed in claim  
23, wherein the loop diagnostic means detaches the devices  
determined as faulty in the loop diagnosis from the loop  
interface, and the loop interface is to be in use again.

[Claim 25] The controller as claimed in claim 24,  
wherein the loop diagnostic means performs the loop  
diagnosis for identifying a faulty device by accessing to  
controlling device connected to another loop interface via  
5 the controlling device connected to the loop interface  
which is in use again.

[Claim 26] The controller as claimed in any one of  
claims 23 to 25, wherein the loop interface is a fibre  
Channel Arbitrated Loop (FC-AL).

[Claim 27] The controller as claimed in any one of  
claims 23 to 25, wherein:

the devices are hard disk devices; and

the controlling devices are enclosure service devices.

5

[Claim 28] A program for an enclosure service device to cause a computer which is connected to one loop interface of multiplexed loop interfaces, having a function of controlling a loop connection switching means for  
5 connecting/detaching devices to/from the loop interfaces, and constituting an enclosure service device comprising an interface for communicating with another enclosure service device connecting to another loop interface each other, to execute; a function as a means for detecting abnormalities  
10 in all loop interfaces; and, at the detecting time, a function as a means for controlling the loop connection switching means so as to detach all devices connecting to the loop interface.

5

[Claim 29] The program for an enclosure service device as claimed in claim 28, comprising a means for detecting commands, which commands are transmitted at a regular interval through the loop interface to which the  
device itself connects have ceased, and informing to other enclosure service devices through the interfaces that the commands have ceased, wherein when all enclosure service devices detect that the commands have ceased, the enclosure service device detects that abnormalities occur in all of

10 the loop interfaces.

[Claim 30] The program for a controller to cause a computer which constitutes a controller connected to one or more devices and to a controlling device having a function of controlling a loop connection switching means for  
5 connecting and detaching the devices to and from the loop interface, via one loop interface of multiplexed loop interfaces, to execute; a function as a means for confirming that all devices connecting to at least one of the loop interfaces have been detached by the controlling  
10 device which detected that abnormalities occurred in all of the multiplexed loop interfaces; and a function as a loop diagnostic means for performing a loop diagnosis to identify a faulty device by accessing to a controlling device connecting to another loop interface through the  
15 interface connecting the controlling devices so as to communicate each other, via the controlling device connecting to the loop interface in which all devices were detached and the loop abnormality has been resolved.

[Claim 31] The program for a controller as claimed in claim 30, wherein the loop diagnostic means detaches the devices determined as faulty in the loop diagnosis from the loop interface, and the loop interface is to be in use

5 again.

[Claim 32] The program for a controller as claimed  
in claim 31, wherein the loop diagnostic means performs the  
loop diagnosis for identifying a faulty device by accessing  
to controlling device connected to another loop interface  
5 via the controlling device connected to the loop interface  
which is in use again.

[Detailed Description pf the Invention]

[0001]

10 [Field of the Invention]

The present invention relates to a method for  
analyzing loop interface failures and a system having a  
function of analyzing loop interface failures.

[0002]

15 [Description of the Related Art]

Recently, an interface which connects devices in a  
loop such as a Fibre Channel Arbitrated Loop (FC-AL) has  
been widely used in disk array apparatuses and the like,  
since it has a simple connecting configuration of cables  
20 and can easily accommodate device extensions. However,  
this type of interface has such a problem that, when  
signals cannot propagate normally in the loop because of  
failures or the like in interface circuits of connected



devices (this is called, for example, loop abnormality or link down), the whole loop cannot be used, and, even though a failure occurs in only one device, all devices connected to the loop cannot be used. In order to cope with this  
5 problem, disk array apparatuses usually have interface circuits for two ports, so that these devices are connected to two independent loops. With this configuration, even when one loop of the dual loop interfaces is out of use because of a failure or the like, accesses can be performed  
10 using the other loop, to thereby improve reliability. Further, this kind of disk array apparatus has a function of identifying a faulty device and restoring the failure promptly when a loop abnormality occurs.

[0003]

15 As an example, Patent Literature 1 discloses a disk array apparatus having two FC-ALs, or loops A and B. In this example, when an abnormality occurs in the loop A, a disk controller in the loop A stops the normal disk processing and transits to a temporary degenerate state,  
20 and a disk controller in the loop B acts the processing for the loop A. The disk controller in the loop A performs a diagnosis of the loop A by itself and bypasses the faulty disk from the loop A to thereby clear the temporary degenerate state of the loop A. With this structure, it is  
25 possible to identify a faulty component while keeping

response to the host, when a loop abnormality occurs.

However, in Patent Literature 1, a loop abnormality is supposed to be an intermittent failure. Therefore, it is assumed that the loop A is not abnormal at the time of  
5 diagnosing the loop A.

[0004]

As another example, Patent Literature 2 discloses a method for analyzing failures, which is applicable to disk array apparatuses having two FC-ALs, or loops A and B, in  
10 which an enclosure service device directly connects to each loop. An enclosure service device is a device for monitoring the environment inside of the casing and managing resources of a device which conforms to the ANSI Standard (NCITS 305-199X). The device also has a function  
15 of controlling a loop connection switching unit which performs bypassing or releasing the bypass of disks connecting to the loop, to which the device itself connects. The enclosure service device directly connecting to the loop acts as a device connecting to the loop interface as  
20 same as the disk connecting to the loop. Therefore, when a unique failure occurs in the loop to which the enclosure service device connects, the disk controller of the loop cannot instructs the enclosure service device through the loop. In order to cope with this problem, in Patent  
25 Literature 2, an interface is provided for communication

between the enclosure service devices connecting to  
respective loops. The interface works in such a manner  
that when a failure occurs in the loop A, it instructs the  
enclosure service device in the loop A to bypass or release  
5 the bypass of disks in the loop A, via the enclosure  
service device in the loop B, for diagnosing the loop A.

[0005]

[Patent Literature 1]

Japanese Patent Publication No. 2002-7077

10 [Patent Literature 2]

Japanese Patent Publication No. 2001-216206

[0006]

[Problem to be Solved by the Invention]

As described above, in the system of disk array  
15 apparatus having a loop interface such as an FC-AL, the  
reliability is improved by using dual loop interfaces and  
bypassing faulty components through an immediate failure  
analysis at the time of loop abnormality. However, in the  
system in which enclosure service devices directly connect  
20 to respective loops, some other problems arise as described  
below, when loop failures occur in the both loops of the  
dual loop interfaces at the same time.

[0007]

A first problem is that the devices connecting to the  
25 loop interfaces cannot be detached from or reconnected to

the loops at all, since the enclosure service devices for controlling the loop connection switching units, which actually perform detachment and reconnection of devices, cannot be accessed from either loop.

5 [0008]

A second problem is that a loop diagnosis for identifying faulty devices, which cause the loop abnormalities, cannot be performed. In order to perform the loop diagnosis, the devices connecting to the loop  
10 interfaces must be detached from and reconnected to the loops. However, the detachment and the reconnection of devices cannot be performed.

[0009]

A third problem is that the system remains  
15 completely stopped, since the loop diagnosis cannot be performed so that faulty components cannot be removed from the loops.

[0010]

The present invention is proposed considering these  
20 problems. An object of the present invention is, in a system of a disk array apparatus or the like having multiplexed loop interfaces in which controlling devices such as enclosure service devices connect to respective loops, to perform detachment and reconnection of devices  
25 connecting to the loop interfaces, and to perform loop

diagnoses so, as to identify faulty devices causing loop abnormalities, to thereby prevent the system from being completely stopped, even when abnormalities occur in all loops.

5 [0011]

[Scheme for Solving the Problems]

A method for analyzing loop interface failures according to the present invention is a method for analyzing failures for a system of a disk array apparatus  
10 or the like, which includes multiplexed loop interfaces such as FC-ALs. In such a system, controlling devices such as enclosure service devices, for controlling loop connection switching means which connect/detach devices such as hard disk devices to/from the respective loop  
15 interfaces, connect to the respective loop interfaces, and interfaces are provided so that the controlling devices can communicate each other. When the controlling devices detect that abnormalities occur in all loop interfaces, the controlling devices control the loop connection switching  
20 means so as to detach all devices connecting to at least one of the loop interfaces.

[0012]

It should be noted that the controlling devices may be configured in the following manner. That is, when  
25 detecting that commands such as heartbeat commands have

ceased, which commands are transmitted at a regular interval through the loop interfaces to which the controlling devices themselves connect, the controlling devices inform to other controlling devices through the  
5 interfaces that the commands have ceased, and when all controlling devices detect that the commands have ceased, they detect that abnormalities occur in all loop interfaces. Further, in the method, loop diagnoses for identifying faulty devices may be performed by accessing to a  
10 controlling device connecting to another loop interface, via the controlling device connecting to the loop interface in which all connected devices were detached and the loop abnormality has been resolved. Further, when abnormalities occur in all multiplexed loop interfaces, a controller,  
15 connecting to the devices and to the controlling device through one loop interface of the multiplexed loop interfaces, may judge whether the loop abnormality of the loop interface to which the controller connects is resolved within a certain period of time, and when the loop  
20 abnormality was resolved within the certain period of time, inquire the controlling device whether it detached all devices. If all devices were detached by the controlling device, countermeasure processing against a double-loop link failure may be performed, which includes the loop  
25 diagnosis by a loop diagnostic means. Further, the devices

determined as faulty in the loop diagnosis may be detached from the loop interface so that the loop interface can be in use again. Further, the loop diagnosis for identifying faulty devices may be performed by accessing to a  
5 controlling device connecting to another loop interface, via the controlling device connecting to the loop interface which is in use again.

[0013]

A system having a function of analyzing loop  
10 interface failures according to the present invention is a system of a disk array apparatus or the like, and comprises, multiplexed loop interfaces such as FC-ALs, and controlling devices such as enclosure service devices having functions of controlling loop connection switching means for  
15 connecting/detaching devices such as hard disk devices to/from the respective loop interfaces. The controlling devices include, interfaces for communicating each other, and means for controlling the loop connection switching means when detecting abnormalities in all loop interfaces,  
20 so as to detach all devices connecting to at least one of the loop interfaces.

[0014]

It should be noted that the controlling device may include means for detecting that commands such as heartbeat  
25 commands have ceased, which commands are transmitted at a

regular interval through the loop interface to which the controlling device itself connects, and informing to other controlling devices through the interfaces that the commands have ceased, and when all controlling devices  
5 detect that the commands have ceased, they detect that abnormalities occur in all loop interfaces. Further, loop diagnostic means may be included for performing loop diagnoses to identify faulty devices by accessing to a controlling device connecting to another loop interface,  
10 via the controlling device connecting to the loop interface in which all connected devices were detached and the loop abnormality has been resolved. Further, a controller connecting to the devices and to the controlling device through one loop interface of the multiplexed loop  
15 interfaces may be included. The controller may, when loop abnormalities occur in all multiplexed loop interfaces, judge whether the loop abnormality in the loop interface to which the controller connects is resolved within a certain period of time, and when the loop abnormality was resolved  
20 within the certain period of time, inquire the controlling device whether it detached all devices, and when all devices were detached by the controlling device, perform countermeasure processing against a double-route link failure including a loop diagnosis by a loop diagnostic  
25 means. The loop diagnostic means may detach the devices



determined as faulty in the loop diagnoses from the loop interface so that the loop interface can be in use again. Further, the loop diagnostic means may perform the loop diagnoses for identifying faulty devices by accessing to a  
5 controlling device connecting to another loop interface, via the controlling device connecting to the loop interface which is in use again.

[0015]

The enclosure service device of the present invention  
10 connects to one loop interface of the multiplexed loop interfaces such as FC-ALs and has a function of controlling a loop connection switching means for connecting/detaching devices such as hard disk devices to/from the loop interfaces. The enclosure service device includes an  
15 interface for communicating with another enclosure service device connecting to another loop interface each other and a means for controlling the loop connection switching means when detecting abnormalities in all loop interfaces so as to detach all devices connecting to the loop interface.

20 [0016]

It should be noted that the enclosure service device of the present invention may include means for detecting that commands, which commands are transmitted at a regular interval through the loop interface to which the device  
25 itself connects have ceased, and informing to other

enclosure service devices through the interfaces that the  
commands have ceased, and when all enclosure service  
devices detect that the commands have ceased, the enclosure  
service devices detect that abnormalities occur in all of  
5 the loop interfaces.

[0017]

The controller of the present invention is a  
controller such as a disk controller or the like which,  
through one loop interface of the multiplexed loop  
10 interfaces such as FC-ALs, connects to one or more devices  
such as hard disk devices and to a controlling device such  
as an enclosure service device having a function of  
controlling a loop connection switching means for  
connecting/detaching the devices to/from the loop interface.  
15 The controller includes, a means for confirming that all  
devices connecting to at least one of the loop interfaces  
have been detached by the controlling device which detected  
that abnormalities occurred in all of the multiplexed loop  
interfaces, and a loop diagnostic means for performing a  
20 loop diagnosis to identify a faulty device by accessing to  
a controlling device connecting to another loop interface  
through the interface connecting the controlling devices so  
as to communicate each other, via the controlling device  
connecting to the loop interface in which all devices were  
25 detached and the loop abnormality has been resolved.

[0018].

The loop diagnostic means of the controller according to the present invention may detach the devices determined as faulty in the loop diagnosis from the loop interface so that the loop interface can be in use again. Further, the loop diagnostic means may perform the loop diagnosis for identifying faulty devices by accessing to a controlling device connecting to another loop interface, via the controlling device connecting to the loop interface which is in use again.

[0019]

[Operation]

In the present invention, it is detected in the controlling devices connecting to respective loop interfaces that abnormalities occur in all of the multiplexed loop interfaces. The controlling devices, upon detection, voluntarily control the loop connection switching means to thereby detach all devices connecting to at least one loop interface. Consequently, if the cause of the loop failure is a fault of any device, the loop abnormality of the loop interface, from which all devices were detached, is resolved and the controlling device connecting to the loop interface can be accessed. Since the controlling devices can communicate each other through interfaces, it is possible to access other controlling

devices via controlling devices which have been able to be accessed. Therefore, devices connecting to any loop interface can be detached and reconnected. Accordingly, it is possible to perform loop diagnoses for identifying  
5 faulty devices causing loop abnormalities, and by detaching the faulty devices, it is also possible to continue operation of the system.

[0020]

[Preferred Embodiment of the Invention]

10 Next, a preferred embodiment will be explained in detail with reference to the accompanying drawings.

[0021]

[Structure]

Referring to Fig. 1, a disk array apparatus 1  
15 according to an embodiment of the present invention connects to hosts A 91 and B 92 via host interfaces A 121 and B 122. The disk array apparatus comprises a disk unit device 5, a cash unit 6, a disk controller A 71, a disk controller B 72, a host controller A 81, and a host  
20 controller B 82.

[0022]

The host controllers A 81 and B 82 perform host services such as command reception, data transfer, status response between the disk array apparatus and the hosts A  
25 91 and B 92, respectively. The host controllers A 81 and B

82 connect to the cash unit 6 and to disk controllers A 71 and B 72 through an inner bus 110, so as to perform data transmission/reception each other. The host controllers A 81 and B 82 and the disk controllers A 71 and B 72 perform  
5 requests for processing such as disk processing to other controllers, and status information of controllers such as information of loop analysis result, via a communicating means between controllers 100,.

[0023]

10 The disk unit device 5 includes: a plurality of FC-AL disks 21 to 2N, each of which has two FC-AL interface ports; loop connection switching units A 31 and B 32; and enclosure service units A 51 and B 52.

[0024]

15 The loop connection switching units A 31 and B 32 are circuits, by which the FC-AL disks 21 to 2N are detached from (hereinafter referred to as bypassed) the FC-ALs A 41 and B 42 or reconnected to (hereinafter referred to as released from bypass) the FC-ALs A 41 and B 42.

20 [0025]

The enclosure service units A 51 and B 52 connect to the disk controllers A 71 and B 72 via the FC-ALs A 41 and B42. The enclosure service units A 51 and B 52 have an interface 130 for communicating each other. The enclosure  
25 service units A 51 and B 52 are devices for monitoring the

inside of the casing and managing the inner resources of devices defined by the ANSI Standard (NCITS 305-199X), and include heartbeat monitors A 511 and B 521, heartbeat receivers A 512 and B 522, and loop connection controllers  
5 A 513 and B 523.

[0026]

The loop connection controllers A 513 and B 523 have functions of controlling the loop connection switching units A 31 and B 32 so as to bypass or release the bypass  
10 of the FC-AL disks 21 to 2N.

[0027]

The heartbeat receivers A 512 and B 522 have functions of receiving commands transmitted at an interval of a certain period of time from the disk controllers A 71  
15 and B 72 through the FC-ALs A 41 and B 42. The commands transmitted from the disk controllers A 71 and B 72 at an interval of a certain period of time are called heartbeat commands hereinafter. The heartbeat commands may be commands defined as dedicated commands or well-known  
20 commands (for example, Receive Diagnostic Results command).

[0028]

The heartbeat monitors A 511 and B 521 monitor receiving conditions of the heartbeat commands at the heartbeat receivers A 512 and B 522, which are in the  
25 enclosure service units. The heartbeat monitors A 511 and

B 521, when detecting that reception of the heartbeat commands have ceased, inform the state to the other heartbeat monitors B 521 and A 511, respectively, through the interface 130. The heartbeat monitors A 511 and B 521  
5 have functions of, when detecting that receptions of the heartbeat commands have ceased in both heartbeat receivers A 512 and B 522, bypassing all FC-AL disks 21 to 2N from the FC-ALs A 41 and B 42 by the loop connection controllers A 513 and B 523. The enclosure service units A 51 and B 52  
10 have functions of, in the case that the receptions of commands have ceased and all disks have been bypassed, recording the state inside and reporting that bypass has been performed responding to inquiries from the disk controllers A 71 and B 72. The reporting function to  
15 inquiries may be realized as, for example, a responding function to the Receive Diagnostic Results commands.

[0029]

Fig. 2 shows an example of the inner structure of the enclosure service unit A 51. The enclosure service unit B  
20 52 has the same structure. In this example, the enclosure service unit A 51 includes a CPU 531, an interface chip 533 connecting to a bus 532 of the CPU 531, a memory 534, a communication unit 535, and a switching unit 536. The interface chip 533 is a portion of the interface between  
25 the enclosure service unit A 51 and the FC-AL A 41. The

communication unit 535 is a device for communicating each other with the enclosure service unit B 52 via the interface 130. The switching unit 536 is formed of, for example, a register for retaining control signals for the loop connection switching unit A 31 and the like. The memory 534 is formed of ROM and RAM, and has an area for storing programs for the enclosure service device (including firmware) as well as storing status information showing the status of the own device and each disk connected to the FC-AL A 41, and the like. The CPU 531 executes the programs for the enclosure service device stored in the memory 534 to thereby control the whole device and realize functions necessary for the device.

[0030]

Referring to Fig. 1 again, the disk controller A 71 forms the FC-AL A 41 between only one port in each of the FC-AL disks 21 to 2N, and the other disk controller B 72 forms the FC-AL B 42 between the other port in each of the FC-AL disks 21 to 2N. The disk controllers A 71 and B 72 perform various disk processing such as reading from and writing to the FC-AL disks 21 to 2N with instructions from the host controllers A 81 and B 82, or by their own determinations of the disk controllers A 71 and B 72. Further, the disk controllers A 71 and B 72 also instruct the enclosure service units A 51 and B 52 to bypass or



release the bypass of the FC-AL disks 21 to 2N, and read information of bypass state and the like from the enclosure service units A 51 and B 52. Further, the disk controllers A 71 and B 72 include temporary degeneracy controllers A 710 and B 720, loop diagnostic units A 711 and B 721, and heartbeat transmitters A 712 and B 722, respectively.

[0031]

The heartbeat transmitters A 712 and B 722 issue heartbeat commands at an interval of a certain period of time to the heartbeat receivers A 512 and B 522, which are components of the enclosure service units A 51 and B 52, respectively. The heartbeat receivers A 512 and B 522 which are components of the enclosure service units A 51 and B 52, as aforementioned, receive the issued heartbeat commands. The heartbeat monitors A 511 and B 521 monitor reception status of the heartbeat commands, and when detecting that heartbeat commands have ceased in both heartbeat receivers A 512 and B 522, all FC-AL disks 21 to 2N are detached from both FC-ALs A 41 and B 42. The period of time, by which the heartbeat monitors A 511 and B 522 determine that the receptions of the heartbeat commands have ceased, may be set by the disk controllers A 71 and B 72. The heartbeat transmitters A 712 and B 722 issue commands to the heartbeat receivers A 512 and B 522 at an interval shorter than the period for determining that the

commands receptions cease by the heartbeat monitors A 511 and B 522.

[0032]

The loop diagnostic units A 711 and B 721 have functions of, when loop abnormalities occur, performing loop diagnoses including bypass and release the bypass of the FC-AL disks in cooperation with each other, and identifying a faulty disk.

[0033]

The temporary degeneracy controllers A 710 and B 720 have functions of controlling cooperation between the host controllers A 81 and B 82 and the disk controllers A 71 and B 72 in order to continue responding to the hosts A 91 and B 92 during loop diagnoses.

[0034]

Fig. 3 shows an example of the inner structure of the disk controller A 71. The disk controller B 72 has the same structure. The disk controller A 71 comprises a CPU 731, an interface chip 733 connecting a bus 732 of the CPU 731, a memory 734, a communication unit 735, and a data transfer unit 736 including a DMA (dynamic memory access) controller and the like. The interface chip 733 is a portion of the interface between the disk controller A 71 and the FC-AL A 41. A loop abnormality detecting mechanism in the disk controller A 71 is typically provided in the interface chip

733. The communication unit 735 is a device for communicating each other with other controllers via a communicating means between controllers 100. The data transfer unit 736 is a device for exchanging data with other controllers through an inner bus 110, as well as exchanging data with the enclosure service unit A 51 and each of the disks 21 to 2N through the interface chip 733 and the FC-AL A 41. The memory 734 including ROM and RAM stores programs for the disk controller (including firmware) and the like. The CPU 731 executes programs for the disk controller stored in the memory 734 to thereby control the whole disk controller and realize functions necessary for the disk controller.

[0035]

#### 15 [Operation]

Next, the operation of the disk array apparatus according to the present embodiment will be explained.

[0036]

Referring to Fig. 1, the host controllers A 81 and B 82 which received instructions from the hosts A 91 and B 92 recognize such necessary information as logic disk numbers (LUN), instruction code types, and logic block addresses (LBA). For example, the host controller A 81 and B 82 which received read instructions from the hosts A 91 and B 92, immediately transfer data from the cash unit 6 to the

host A 91 and B 92, if the designated data exists in the cash unit 6. If the designated data does not exist in the cash unit 6, the host controllers A 91 and B 92 instruct the disk controllers A 71 and B 72 to store data read out from the FC-AL disks 21 to 2N in the cash unit 6, and when the data is stored in the cash unit 6, transfer the data to the host A 91 and B 92. Further, if the host controllers A 81 and B 82 received write instructions from the host A 91 and B 92, for example, they store the data received from the hosts A 91 and B 92 in the data in the cash unit 6. This data is written in the FC-AL disks 21 to 2N by the disk controllers A 71 and B 72, through instructions from the host controllers A 81 and B 82 to the disk controllers A 71 and B 72 to write the data into the disks, or through detection by the disk controllers A 71 and B 72 that unwritten data exists in the cash unit 6. Generally, the two disk controllers A 71 and B 72 are used to share the FC-AL disks 21 to 2N to which processing is assigned, so as to divide the loads.

[0037]

Next, a process, when loop abnormalities occur in the FC-AL A 41 and the FC-AL B 42, will be explained.

[0038]

When a loop abnormality occurs only in the FC-AL A 41, signals cannot propagate on the FC-AL A 41. Therefore, the

disk controller A 71 detects the state as same as conventional examples. At this time, the heartbeat commands, which are regularly transmitted by the heartbeat transmitter A 712 in the disk controller A 71, have not  
5 been received in the heartbeat receiver A 512 any more, so that the heartbeat monitor A 511 detects that a loop abnormality occurs in the FC-AL A 41. In this case, since the other FC-AL B 42 is in the normal state, a control for bypassing disks 21 to 2N from the FC-AL A 41 is not  
10 performed.

[0039]

In contrast, when a loop abnormality occurs only in the FC-AL B 42, signals cannot propagate on the FC-AL B 42. Therefore, the disk controller B 72 detects the state as  
15 same as conventional examples. At this time, the heartbeat commands, which are regularly transmitted by the heartbeat transmitter B 722 in the disk controller B 72, have not been received in the heartbeat receiver B 522 any more, so that the heartbeat monitor B 521 detects that a loop  
20 abnormality occurs in the FC-AL B 42. In this case, since the other FC-AL A 41 is in the normal state, a control for bypassing disks 21 to 2N from the FC-AL B 42 is not performed.

[0040]

25 When loop abnormalities occur in both FC-ALs A 41 and

B 42, the disk controller A 71 detects the loop abnormality in the FC-AL A41, and the disk controller B 72 detects the abnormality in the FC-AL B 42. Further, the heartbeat monitors A 511 and B 521 in the enclosure service units A 51 and B 52 detect that loop abnormalities occur in both FC-ALs A 41 and B 42. Then, according to an instruction from the loop connection controller A 513, the loop connection switching unit A 31 is controlled, so that all disks 21 to 2N are bypassed from the FC-AL A 41. At the same time, the loop connection switching unit B 32 is controlled according to an instruction from the loop connection controller B 523, so that all disks 21 to 2N are bypassed from the FC-AL B 42.

[0041]

Fig. 4 is a flowchart showing a processing example when the disk controllers A 71 and B 72 detect loop abnormalities in their own loops. Since the disk controllers A 71 and B 72 perform the same processing, only the disk controller A 71 will be explained below as an example.

[0042]

The disk controller A 71, when detects a loop abnormality in the FC-AL A 41 (S101), inquires the disk controller B 72 about the loop status of another FC-AL B 42 via the communicating means between controllers 100 (S102).

Responding to the inquiry, the disk controller B 72 replies to the disk controller A 71 whether the loop status of the FC-AL B 42 is normal or abnormal via the communicating means between controllers 100. If the FC-AL B 42 is not in the abnormal state but in the normal state (NO in S103), the disk controller A 71 performs countermeasure processing against a single-route link failure, which is the process for a case that a loop abnormality occurs in only one loop (S104). The details of the countermeasure processing against a single-route link failure will be explained later. On the other hand, if a loop abnormality occurs in the FC-AL B 42 as well (YES in S103), the disk controller A 71 proceeds to the step S105.

[0043]

In the step S105, the disk controller A 71 waits for a certain period of time. The waiting period is a little longer than a period necessary for the enclosure service units A 51 and B 52 to voluntarily bypass the disks 21 to 2N from the FC-ALs A 41 and B 42 when the loop abnormalities occur in both FC-ALs A 41 and B 42. When the waiting period passed, the disk controller A 71 judges whether the loop abnormality of the FC-AL A 41 is resolved (S106). If the abnormality of the own loop is resolved (YES in S106), the disk controller A 71 inquires the enclosure service unit A 51 that whether all disks 21 to 2N

were bypassed since receptions of the heartbeat commands ceased in both loops, through the FC-AL A 41 in which the loop abnormality is resolved (S107). Responding to the inquiry, if the enclosure service unit A 51 replies through  
5 the FC-AL A 41 that it bypassed all disks (YES in S108), the disk controller A 71 performs countermeasure processing against a double-routes link failure, which is a process performed when loop abnormalities occur in both FC-ALs A 41 and B 42 (S109). The details of the countermeasure  
10 processing against a double-route link failure will be described later.

[0044]

On the other hand, when the enclosure service unit A 51 replies that no bypass of all disks was performed (NO in  
15 S108), the disk controller A 71 proceeds on the understanding that the loop abnormality was an intermission failure and was naturally cured. For a case that the disk controller A 71 waited for a certain period of time in the step S105 but the loop abnormality in the FC-AL A 41 was  
20 not resolved (NO in S106), the cause of the loop abnormality exists in devices other than the disks 21 to 2N, for example a failure of the enclosure service unit A 51 itself. Therefore, the disk controller A 71 performs countermeasure processing against failure corresponding to  
25 the cause. Since the countermeasure processing against



failure is not directly related to the present invention,  
the explanation is omitted.

[0045]

In the example of processing in Fig. 4, when the  
5 other loop is also in the abnormal state (YES in S103), the  
disk controller A 71 waits for a certain period of time  
(S105) and then judges whether the abnormal state of the  
own loop is resolved (S106). However, this part of  
processing may be changed to that shown in Fig. 5. That is,  
10 when the other loop is also in the abnormal state (YES in  
S103), the disk controller performs processing including  
the process of S106 for judging whether the abnormal state  
of the own loop has been resolved and the process of S110  
for judging whether a certain period of time has passed.  
15 If the abnormal state of the own loop has been resolved,  
the disk controller A 71 proceeds to the step S107, and if  
the abnormality of the own loop has not been resolved  
although a certain period of time passed (YES in S110),  
proceeds to other countermeasure processing against failure.  
20 In Fig. 4, it is necessary to wait for a certain period of  
time even though the loop failure was an intermission  
failure and was resolved immediately. However, the process  
shown in Fig. 5 has an advantage that such a waiting period  
is not needed.

25

[0046]

Next, the countermeasure processing against a single-route link failure in the step S104 will be explained with an example that a loop abnormality occurs in the FC-AL A 41. Of course, the same operation is performed in the case of  
 5 the FC-AL B 42.

[0047]

Fig. 6 is a flowchart showing an example of the countermeasure processing against a single-route failure (S104). As an example, assuming that a loop abnormality  
 10 such as link down continues in the FC-AL A 41 caused by a fault in any one of the FC-AL disks 21 to 2N (S1041). In this state, the disk controller A 71 cannot access to the enclosure service unit A 51 and the FC-AL disks 21 to 2N. The temporary degeneracy unit A 710 in the disk controller  
 15 A 71 stops executing the normal disk processing (S1042) (the state in which the normal function stops is called a temporary degeneracy state), and informs the host controllers A 81 and B 82, and the other disk controller B 72 that the state is transited to the temporary degeneracy  
 20 state (temporary degeneracy information), via the communicating means between controllers 100 (S1043).

[0048]

The disk controller B 72 and the host controllers A 81 and B 82, upon receipt of the temporary degeneracy  
 25 information, operate the system in the temporary degenerate

state of the loop, A (S1044). More specifically, the temporary degeneracy controller B 720 in the disk controller B 72, which received the temporary degeneracy information, first resets the FC-AL disks 21 to 2N, and  
5 cancels remaining processes in the FC-AL disks 21 to 2N caused by abandonment of disk processing by the regenerated disk controller A 71. Further, the disk controller B 72 performs disk processing instructed by the host controllers A 81 and B 82, and disk processing determined by itself,  
10 for all of the FC-AL disks 21 to 2N. On the other hand, the host controllers A 81 and B 82, upon receipt of the temporary degeneracy information, request to the substitute disk controller B 72 to perform uncompleted disk processing which has been requested to the degenerated disk controller  
15 A 71. Further, during the time that the disk controller A 71 is temporary degenerated, every disk processing by the new host I/O is requested to the substitute disk controller B 72. Accordingly, since the disk controller B 72 succeeds processing during the time of the disk controller A 71  
20 being degenerated, it is possible to continue responding to the hosts.

[0049]

Next, the loop diagnostic unit A 711 in the disk controller A 71 which is temporary degenerated and the loop  
25 diagnostic unit B 721 in the disk controller B 72 cooperate

each other to perform diagnostic processing for identifying a faulty component of the disks 21 to 2N connected to the FC-AL A 41 (S1045). A specific example of the loop diagnostic processing of the step S1045 will be described below.

[0050]

First, the loop diagnostic unit A 711 in the disk controller A 71 instructs, via the communicating means between controllers 100, the loop diagnostic unit B 721 in the disk controller B 72 to bypass, for example, the disk 21 among the FC-AL disks 21 to 2N from the FC-AL A 41. The disk controller B 72, upon receipt of the instruction, instructs the enclosure service unit B 52 of the same bypass, through the FC-AL B 42, and the enclosure service unit B 52 instructs the enclosure service unit A 51 of the same bypass, through the interface 130. The loop connection controller A 513 in the enclosure service unit A 51, upon receipt of the instruction, controls the loop connection switching unit A 31 so as to detach the disk 21 from the FC-AL A 41. The disk controller A 71 judges whether the loop abnormality in the FC-AL A 41 has been resolved, and if resolved, identifies the disk 21 as the faulty disk. On the other hand, if the loop abnormality still continues, the next disk 22 is bypassed from the FC-AL A 41 with the same procedure as that of the disk 21, and

checked whether the disk 22 is the faulty disk or not.  
This process is repeated through the last disk 2N until the  
faulty disk is identified.

[0051]

5           When the faulty disk is identified through this  
process, the disk controller A 71 detaches the faulty disk  
and releases the normal disks from bypass so as to  
reconnects them to the FC-AL A 41 (step S1046). For  
example, in a case that the disk 22 is the faulty disk,  
10 only the faulty disk 22 is detached from the FC-AL A 41 and  
the normal disks are connected to the FC-AL A 41, as shown  
in Fig. 7.

[0052]

Subsequently, the disk controller A 71 informs, via  
15 the communicating means between controller 100, the host  
controllers A 81 and B 82 and the other disk controller B  
72 that the temporary degenerate state has been cleared and  
transited to the normal state (temporary degeneracy cleared  
information) (S1047). The disk controller A 71, which  
20 cleared the temporary degenerate state, resumes disk  
processing of the normal function. The disk controller B  
72, when received the temporary degeneracy cleared  
information, stops processing of the disks handled by the  
disk controller A 71 in which the temporary degenerate  
25 state was cleared, and takes charge of processing the

remaining disks including the disk bypassed from the other loop through the loop diagnosis. The host controllers A 81 and B 82, upon receipt of the temporary degenerate cleared information, request disk processing to the disk

5 controllers A 71 and B 72 corresponding to the aforementioned handling of the disks. As for the disk determined as faulty, it is informed to the maintenance staff or users that the disk is required to be replaced, by a maintenance terminal (not shown) connecting to the disk  
10 array apparatus 1 or a host (not shown) for managing the disk array connected through a host path, or the like.

[0053]

The specific example of the loop diagnostic processing described above is just an example and the  
15 present invention is not limited to the aforementioned example. For example, a loop diagnosis may be performed with the procedure shown in Fig. 5 of the aforementioned Patent literature 2. Further, it may be performed in such a manner that all disks 21 to 2N connecting to the FC-AL A  
20 41 are bypassed for a while and releasing them one by one so as to check each disk for a failure.

[0054]

Next, the countermeasure processing against a double-route link failure (S109) shown in Fig. 4 will be explained.

25 [0055]

Fig. 8. is a flowchart showing an example of the countermeasure processing against a double-system link failure S109. Before starting the countermeasure processing against a double-route link failure, all disks 21 to 2N are bypassed from the FC-AL A 41 and B 42 by the enclosure service units A 51 and B 52. In this state, both disk controllers A 71 and B 72 cannot perform normal disk processing. Therefore, the temporary degeneracy controllers A 710 and B 720 in the disk controllers A 71 and B 72 stop normal disk processing and let the state to be a temporary degenerate state (S1091), and inform the host controllers A 81 and B 82 that the state transited to the temporary degenerate state (temporary degeneracy information) (S1092), via the communicating means between controllers 100. The host controllers A 81 and B 82, upon receipt of the temporary degeneracy information, suspend to receive requests from the hosts A 91 and B 92, since all disk controllers A 71 and B 72 are in the temporary degenerate state (S1093).

20 [0056]

Next, the loop diagnostic units A 711 and B 721 in the disk controllers A 71 and B 72 first cooperatively perform diagnostic processing for identifying a faulty component among a plurality of disks 21 to 2N connecting to either one of FC-ALs, for example, the FC-AL A 41 (S1094).

A specific example of the loop diagnostic processing of the step S1094 will be explained below.

[0057]

First, the loop diagnostic unit A 711 in the disk  
5 controller A 71 instructs, via the communicating means  
between controllers 100, the loop diagnostic unit B 721 in  
the disk controller B 72 to connect (release the bypass of)  
a disk among the FC-AL disks 21 to 2N, for example, the  
disk 21 to the FC-AL A41. The disk controller B 72, upon  
10 receipt of the instruction, instructs through the FC-AL B  
42 the enclosure service unit B 52 to release the bypass as  
well, and the enclosure service unit B 52 instructs the  
enclosure service unit A 51 to release the bypass as well  
through the interface 130. The loop connection controller  
15 A 513 of the enclosure service unit A 51, upon receipt of  
the instruction, controls the loop connection switching  
unit A 31 to connect the disk 21 to the FC-AL A 41. The  
disk controller A 71 judges whether the loop abnormality of  
the FC-AL A 41 occurs again, and if so, identifies the disk  
20 21 as the faulty disk. If the loop abnormality does not  
occur again, the disk 21 is identified as a normal disk.

[0058]

In a case that the disk 21 is identified as a faulty  
disk, the loop diagnostic unit A 711 of the disk controller  
25 A 71 instructs the enclosure service unit A 51 to bypass



the disk 21, through the same channel as used in  
instructing the release of the bypass, that is, a channel  
via the communicating means between controllers 100, the  
loop diagnostic unit B 721, the enclosure service unit B 52,  
5 and the interface 130. Then, after detaching the faulty  
disk 21 from the FC-AL A 41, the loop diagnostic unit A 711  
performs a diagnosis of the disk 22 as same as that of the  
disk 21. In a case that the disk 21 is not the faulty disk,  
the loop diagnostic unit A 711 performs a diagnosis of the  
10 disk 22 as same as that of the disk 21 while the disk 21  
connects to the FC-AL A 41. This procedure is repeated for  
all remaining disks. When the loop diagnosis of the FC-AL  
A 41 completed, only the normal disks connect to the FC-AL  
A 41.

15 [0059]

The above explanation illustrates a case that when  
the disk controller A 71 connects the disks 21 to 2N to the  
FC-AL A 41, the instruction to release the bypass is  
transmitted to the enclosure service unit A 51 via the  
20 other disk controller B 72, the FC-AL B 42, and the  
enclosure service unit B 52. However, the instruction to  
release the bypass may be directly transmitted to the  
enclosure service unit A 51 through the FC-AL A 41. It  
should be noted that if a disk, released from the bypass,  
25 is the faulty disk, the loop abnormality occurs again in

the FC-AL A 41. Therefore, when detaching the disk again,  
it is required to transmit the instruction of the bypass to  
the enclosure service unit A 51 via the other disk  
controller B 72, the FC-AL B 42, and the enclosure service  
5 unit B 52.

[0060]

Subsequently, the disk controller A 71 informs the  
host controllers A 81 and B 82, by the communicating means  
between controllers 100, that the temporary degenerate  
10 state of the loop A is cleared and transited to the normal  
state (temporary degenerate cleared information) (S1095).  
With this information, the operation of the system resumes  
in the temporary degenerate state of the loop B (S1096).  
The host controllers A 81 and B 82, which received the  
15 temporary degenerate cleared information of the loop A,  
request the disk controller A 71, in which the temporary  
degenerate state is cleared, to perform the uncompleted  
disk processing again which has been requested to the disk  
controllers A 71 and B 72 which are temporary degenerated.  
20 Further, the host controllers A 81 and B 82 resume  
accepting requests from the hosts A 91 and B 92, and  
request the disk controller A 71 to perform every disk  
processing by the new host I/O. The disk controller A 71  
cancels disk processing remaining in the all normal FC-AL  
25 disks, and then performs disk processing instructed by the

host controllers A 91 and B 92 and disk processing determined by the disk controller A 71, for the all normal FC-AL disks. With this process, it is possible to minimize the period in which the system operation completely stops.

5 [0061]

Next, the loop diagnostic unit A 711 in the disk controller A 71 which cleared the temporary degeneracy and the loop diagnostic unit B 721 in the disk controller B 72 which is temporary degenerated, cooperatively perform  
10 diagnostic processing to identify a faulty component among the disks 21 to 2N connecting to the FC-AL B 42 (S1097). The loop diagnostic processing of the step S1097 is performed as follows, as same as the processing of the step S1094.

15 [0062]

First, the loop diagnostic unit B 721 of the disk controller B 72 instructs the enclosure service unit B 52 to connect (release the bypass of) a disk, for example, the disk 21, among the FC-AL disks 21 to 2N via the  
20 communicating means between controllers 100, the loop diagnostic unit 711 in the disk controller A 71, the FC-AL A 41, the enclosure service unit A 51, and the interface 130. The loop connection controller B 523 in the enclosure service unit B 52, upon receipt of the instruction,  
25 controls the loop connection switching unit B 32 so as to

connect the disk 21 to the FC-AL B 42. The disk controller B 72 judges whether the loop abnormality occurs in the FC-AL B 42 again, and if so, identifies the disk 21 as a faulty disk. If the loop abnormality does not occur again, the disk 21 is identified as a normal disk. In the case that the disk 21 is identified as a faulty disk, the loop diagnostic unit B 721 of the disk controller B 72 instructs the loop connection switching unit B 32 to bypass the disk 21, through the same channel as used in instructing the release of the bypass. Then, after detaching the faulty disk 21 from the FC-AL B 42, the loop diagnosis unit B 52 performs diagnosis of the disk 22 as same as that of the disk 21. In the case that the disk 21 is not the faulty disk, the loop diagnostic unit B 721 performs a diagnosis of the disk 22 as same as that of the disk 21 while the disk 21 connects to the FC-AL B 42. This procedure is repeated for all remaining disks. When the loop diagnosis of the FC-AL B 42 completed, only the normal disks connect to the FC-AL B 42. Same as the case of the step S1094, the disk controller B 72 may transmit the instruction of releasing the bypass directly to the enclosure service unit B 52 through the FC-AL B 42.

[0063]

Subsequently, the disk controller B 72 informs, by the communicating means between controllers 100, the host

controllers A 81 and B 82 and the other disk controller A 71 that the temporary degenerate state of the loop B has been cleared and transited to the normal state (temporary degenerate cleared information) (S1098). With this process, 5 the operation of the system continues using both loops A and B (S1099). That is, the disk controller B 72 which cleared the temporary degenerate state resumes disk processing of the normal function. The disk controller A 71, upon receipt of the temporary degenerate cleared 10 information, stops processing of disks of which the disk controller B 72 cleared the temporary degenerate takes charge. The host controllers A 81 and B 82, upon receipt of the temporary degenerate cleared information of the loop B, request disk processing to the disk controllers A 71 and 15 B 72 corresponding to their responsibilities to the aforementioned disks. It should be noted that as for the disk determined as faulty, it is informed to the maintenance staff or the users, by a maintenance terminal (not shown) connecting to the disk array apparatus 1 or a 20 host (not shown) for managing the disk array connecting via a host path that the disk is required to be replaced.

[0064]

The aforementioned specific example of the loop diagnosis described in the steps S1094 and S1097 is just an 25 example, and the present invention is not limited to this

specific example.. As an example of the diagnostic method in the step S1094, it is acceptable to connect a plurality of disks at the same time. That is, connecting a half number of disks to the FC-AL A 41 at the same time and if a  
5 loop abnormality does not occur, connecting the remaining half number of disks to the FC-AL A 41 at the same time. In this case, if a loop abnormality occurs when connecting a plurality of disks, it means that a faulty disk exists in those disks. Therefore, the process of identifying the  
10 faulty disk may be performed to the disks. The same loop diagnostic method can be used in the step S1097.

[0065]

Practically, there are many cases that abnormalities occur in the both loops because of a failure of one disk.  
15 Therefore, in the step S1097, it is acceptable to check whether the loop abnormality occurs again by connecting all disks other than the disk determined as faulty to the FC-AL B 42, considering the result of the step S1094. However, there is a case, though it is rare, that one loop in each  
20 of the two disks fails at the same time so that two loop abnormalities occur. In this case, the loop abnormality occurs again. Therefore, the diagnosis should be continued so as to identify another faulty disk causing the loop abnormality in the FC-AL B 42.

25 [0066]

[Other embodiments]

In the aforementioned embodiment, when the heartbeat monitors A 511 and B 521 in the enclosure service units A 51 and B 52 detect both loop abnormalities, all disks 21 to 5 2N are detached from the FC-AL A 41 and from the FC-AL B 42 by the loop connection controllers A 513 and B 523, so as to resolve both loop abnormalities. However, the present invention is not limited to the aforementioned embodiments. In the present invention, it is acceptable that all disks 10 21 to 2N are detached from one FC-AL, for example, the FC-AL B 42, but are connected to the other FC-AL A 41. In this case, a loop abnormality in the FC-AL B 42 is resolved but a loop abnormality in the FC-AL A 41 is not resolved. This state is quite similar to that of a loop abnormality 15 which occurs only in one loop. In this case, a loop diagnosis to identify a faulty disk among the disks connected to the FC-AL A 41 can be performed by accessing from the disk controller A 71 to the enclosure service unit A 51 through the FC-AL B 42 having no loop abnormality, 20 with the same method described in the step S1045 shown in Fig. 6. Then, detaching the disk determined as faulty in the loop diagnosis, the loop abnormality in the FC-AL A 41 can be resolved. Then, a loop diagnosis of the other FC-AL B 42 can be performed by the same method as that of the 25 step S1045.

[0067].

In the aforementioned embodiment, the present invention is applied to the disk array apparatus in which one FC-AL connects to each of the disk controllers A 71 and B 72. However, the present invention is not limited to this structure. The present invention may be applied to a disk array apparatus in which a plurality of FC-ALs connect to each of the disk controllers A 71 and B 72, an example of which is shown in Fig. 9.

10 [0068]

A disk array apparatus shown in Fig. 9 includes two disk unit devices, or a disk unit device 5 and the similar disk unit device 5X. FC-ALs A 41 of the both disk unit devices connect to a disk controller A 71, and FC-ALs B 42 of the both disk unit devices connect to a disk controller B 72. That is to say, two independent disk unit devices 5 and 5X connect to the disk controllers A 71 and B 72 in parallel. In the disk array apparatus shown in Fig. 1 which only includes the disk unit 5, disk array is formed by using the disks in the disk unit 5. However, the disk array apparatus shown in Fig. 9 can form the disk array by combining disks in the different disk unit device in addition to the disk array shown in Fig. 1. For example, a disk 21 in the disk unit device 5 and a disk 21 in the disk unit device 5X can form a disk array of RAID1. In this

15  
20  
25



case, even when dual loop abnormalities occur in either one of the disk unit devices, disk processing can be continued in the other disk unit device, so that the reliability is improved. Note here that when dual loop abnormalities occur in each of the disk unit devices 5 and 5X, processing is basically the same as that of the disk array apparatus shown in Fig. 1.

[0069]

In the aforementioned embodiments, the present invention is applied to a disk array apparatus in which one enclosure service unit connects to one FC-AL. However, the present invention is not limited to this structure, and it is applicable to a disk array apparatus in which a plurality of enclosure service units connect to one FC-AL. An example of which is shown in Fig. 10.

[0070]

In a disk array apparatus shown in Fig. 10, the number of disks connecting to each of the FC-ALs A 41 and B 42 is extended by a disk unit device 5Y (extension apparatus) which is similar to the disk unit device 5. In this case, each of the basic apparatus having the disk unit device 5 and the extension apparatus having the disk unit device 5Y has one enclosure service unit per one loop, respectively. Therefore, enclosure service units 51 and 52 arranged in respective loops in the disk unit device 5 are

connected by an interface 130 so as to communicate each other, and enclosure service units 51 and 52 arranged in the respective loops in the disk unit device 5Y are also connected by an interface 130 so as to communicate each other. Further, heartbeat commands from disk controllers A 71 and B 72 are transmitted to all enclosure service units connected to the same loop. Each enclosure service unit, when detecting loop abnormalities in the both loop, detaches all disks connecting to the basic apparatus or the extension apparatus, in which the enclosure service unit itself is provided.

[0071]

Embodiments of the present invention have been explained above. However, the present invention is not limited to the aforementioned embodiments and is possible to accommodate other various additions and modifications. For example, although the enclosure service unit detects a loop abnormality by recognizing that reception of heartbeat commands ceased, it is acceptable that the same function as the loop abnormality detecting function in the disk controller may be provided in the enclosure service unit.

[0072]

[Effects of the Invention]

As described above, the present invention has the following effects.

[0073].

In a system including, controlling devices such as enclosure service devices for controlling loop connection switching means which perform connecting/detaching of devices to/from loops, and multiplexed loop interfaces to which the controlling devices directly connect, it is possible to perform detaching and reconnecting devices even though loop abnormalities occur at the same time in all of the loop interfaces. The reason is as follows. When abnormalities occur in all of the multiplexed loop interfaces, they are detected by the controlling devices. The controlling devices voluntarily control the loop connection switching means so as to detach all devices connected to at least one loop interface from the loop, to thereby resolve at least one loop abnormality in one loop interface. Accordingly, it is possible to access to the controlling devices connected to the loop, and via the controlling devices, it is also possible to access to controlling devices connected to other loops.

20 [0074]

In a system including, controlling devices such as enclosure service devices for controlling loop connection switching means which perform connecting/detaching of devices to/from loops, and multiplexed loop interfaces to which the controlling devices directly connect, it is

possible to perform loop diagnoses for identifying faulty devices causing the loop abnormalities even when loop abnormalities occur at the same time in all of the loop interfaces. The reason is as follows. In order to perform  
5 loop diagnoses, it is required to detach and reconnect the devices connecting to the loop interfaces, which can be performed in the present invention.

[0075]

In a system including, controlling devices such as  
10 enclosure service devices for controlling loop connection switching means which perform connecting/detaching of devices to/from loops, and multiplexed loop interfaces to which the controlling devices directly connect, it is possible to prevent the system from being completely  
15 stopped even when loop abnormalities occur at the same time in all of the loop interfaces. The reason is that the loop diagnoses can be performed as aforementioned, so that the faulty components can be removed from the loops and the operation of the system can be resumed.

20 [Brief Description of the Drawings]

[Fig. 1]

A block diagram showing an example of a disk array apparatus to which the present invention is applied.

[Fig. 2]

25 A block diagram showing an example of the inner

structure of an enclosure service unit according to a disk array apparatus to which the present invention is applied.

[Fig. 3]

5 A block diagram showing an example of the inner structure of a disk controller according to a disk array apparatus to which the present invention is applied.

[Fig. 4]

10 A flowchart showing an example of a process when a disk controller of a disk array apparatus detects a loop abnormality.

[Fig. 5]

A flowchart showing another example of a process when a disk controller of a disk array apparatus detects a loop abnormality.

15 [Fig. 6]

A flowchart showing an example of a countermeasure processing against a single-route link failure.

[Fig. 7]

20 A diagram showing a state of a disk array apparatus in which a faulty disk is detached and only normal disks are connected.

[Fig. 8]

A flowchart showing an example of countermeasure processing against a double-route link failure.

25 [Fig. 9]

A block diagram showing another example of a disk array apparatus to which the present invention is applied.

[Fig. 10]

A block diagram showing still another example of a disk array apparatus to which the present invention is applied.

[Description of Symbols]

1 disk array apparatus  
 5, 5X, 5Y disk unit device  
 10 6 cash unit  
 21-2N FC-AL disk  
 31 loop connection switching unit A  
 32 loop connection switching unit B  
 41 FC-AL A  
 15 42 FC-AL B  
 51 enclosure service unit A  
 52 enclosure service unit B  
 71 disk controller A  
 72 disk controller B  
 20 81 host controller A  
 82 host controller B  
 91 host A  
 92 host B  
 100 communication means between controllers  
 25 110 inner bus

	121	host interface A
	122	host interface B
	130	interface
	511	heartbeat monitor A
5	512	heartbeat receiver A
	513	loop connection controller A
	521	heartbeat monitor B
	522	heartbeat receiver B
	523	loop connection controller B
10	531	CPU
	532	bus
	533	interface chip
	534	memory
	535	communication unit
15	536	switching unit
	710	temporary degeneracy controller A
	711	loop diagnostic unit A
	712	heartbeat transmitter A
	720	temporary degeneracy controller A
20	721	loop diagnostic unit B
	722	heartbeat transmitter B
	731	CPU
	732	bus
	733	interface chip
25	734	memory

735 communication unit

736 data transfer unit





[Document Title] Abstract

[Abstract]

[Object] A disk array apparatus is provided, which has dual FC-ALs to each of which an enclosure service unit connects, and is capable of performing loop diagnoses including detachment and reconnection of devices even when abnormalities occur in all loops.

[Scheme] The enclosure service units 51, 52 can communicate each other through an interface 130. Heartbeat monitors 511, 521, when detecting that heartbeat commands transmitted through the FC-ALs 41, 42 have ceased in both loops, detach all disks 21 to 2N connecting to the FC-ALs 41, 42 to thereby resolve the loop abnormalities. Then, loop diagnostic units 711, 721 cooperatively perform loop diagnoses including reconnection of disks to the FC-ALs 41, 42, identify faulty disks, detach the faulty disks, so as to continue the operation of the system.

[Selected Drawing] Fig. 1



FIG.1

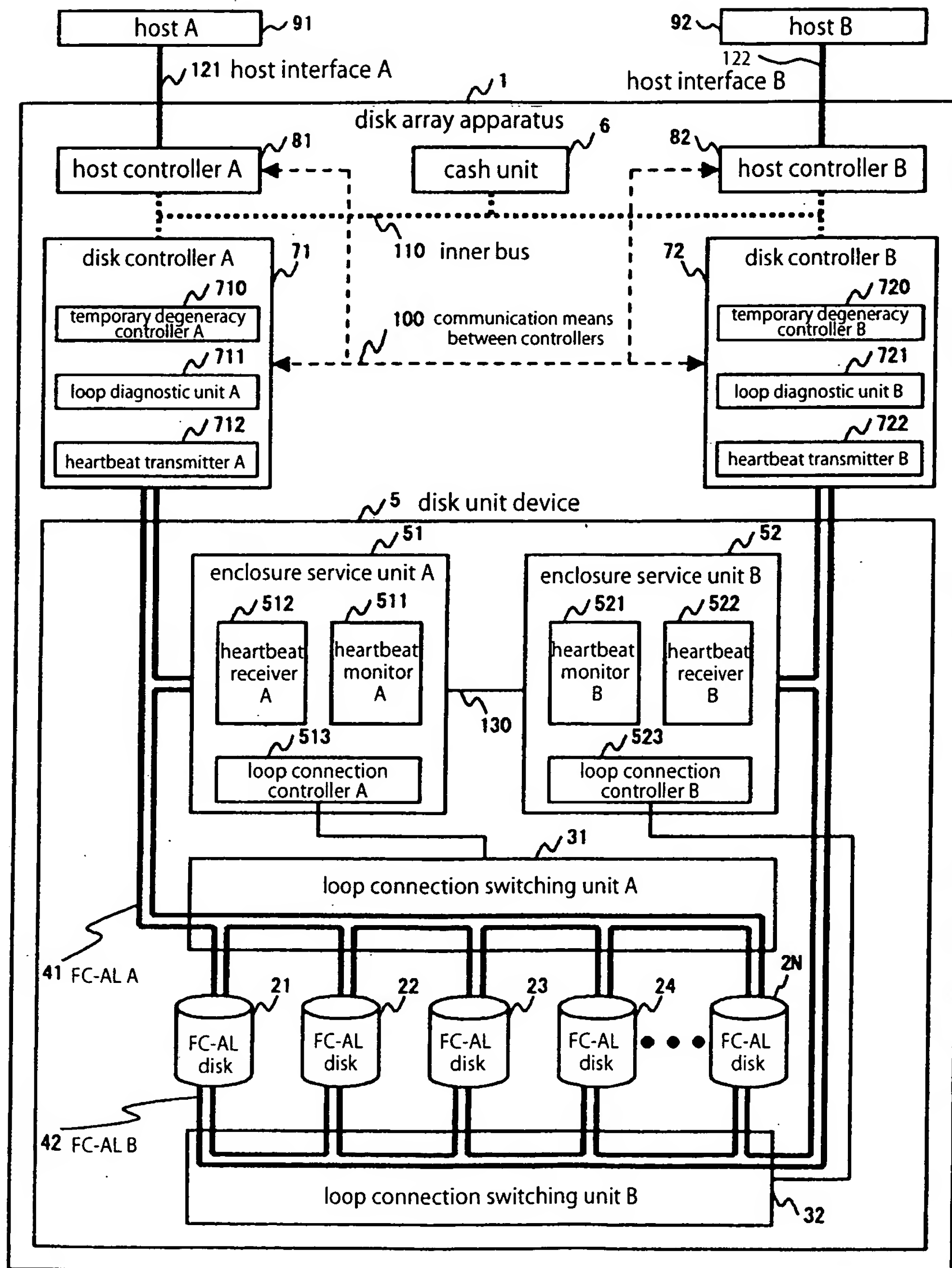


FIG.2

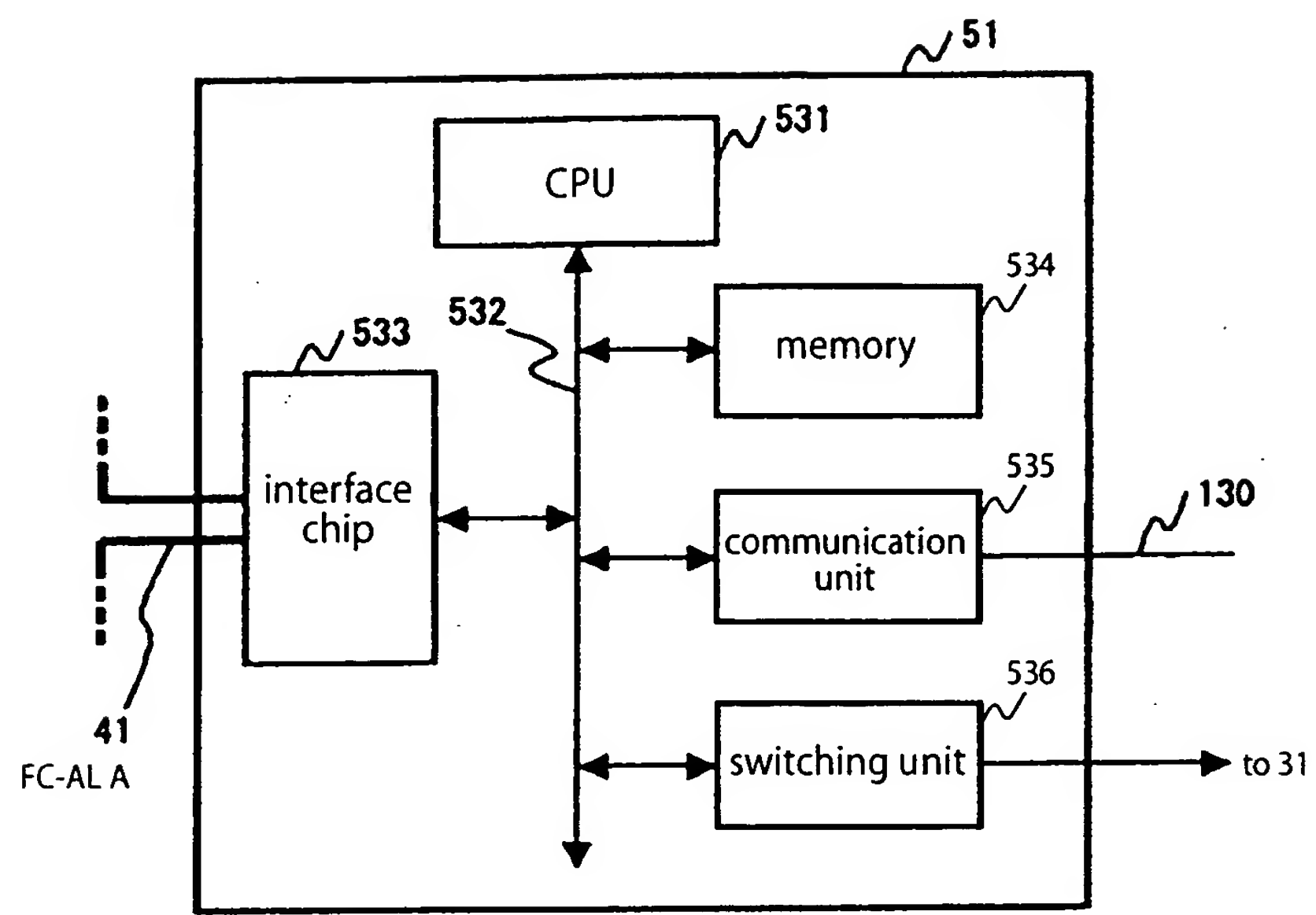


FIG.3

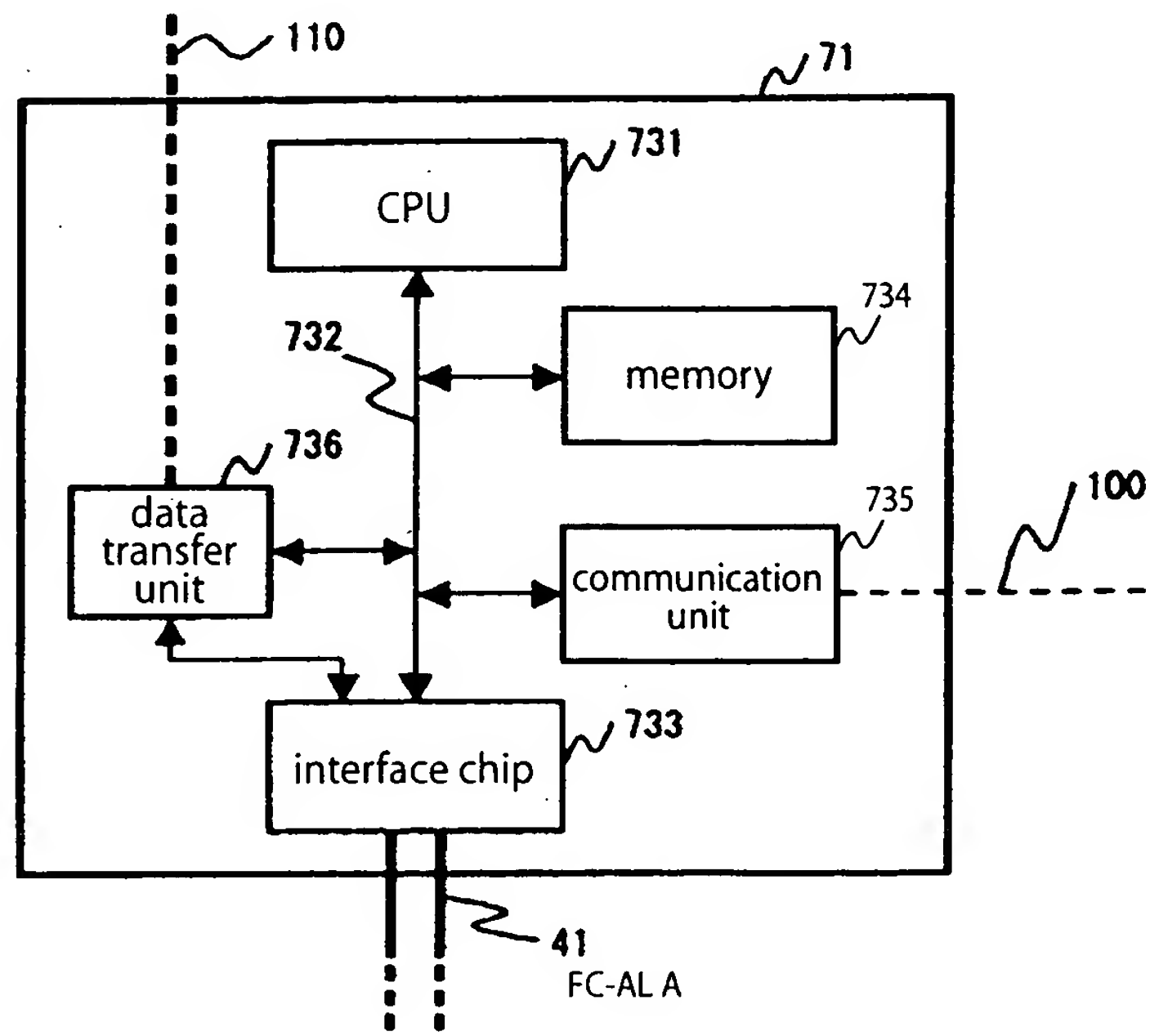


FIG.4

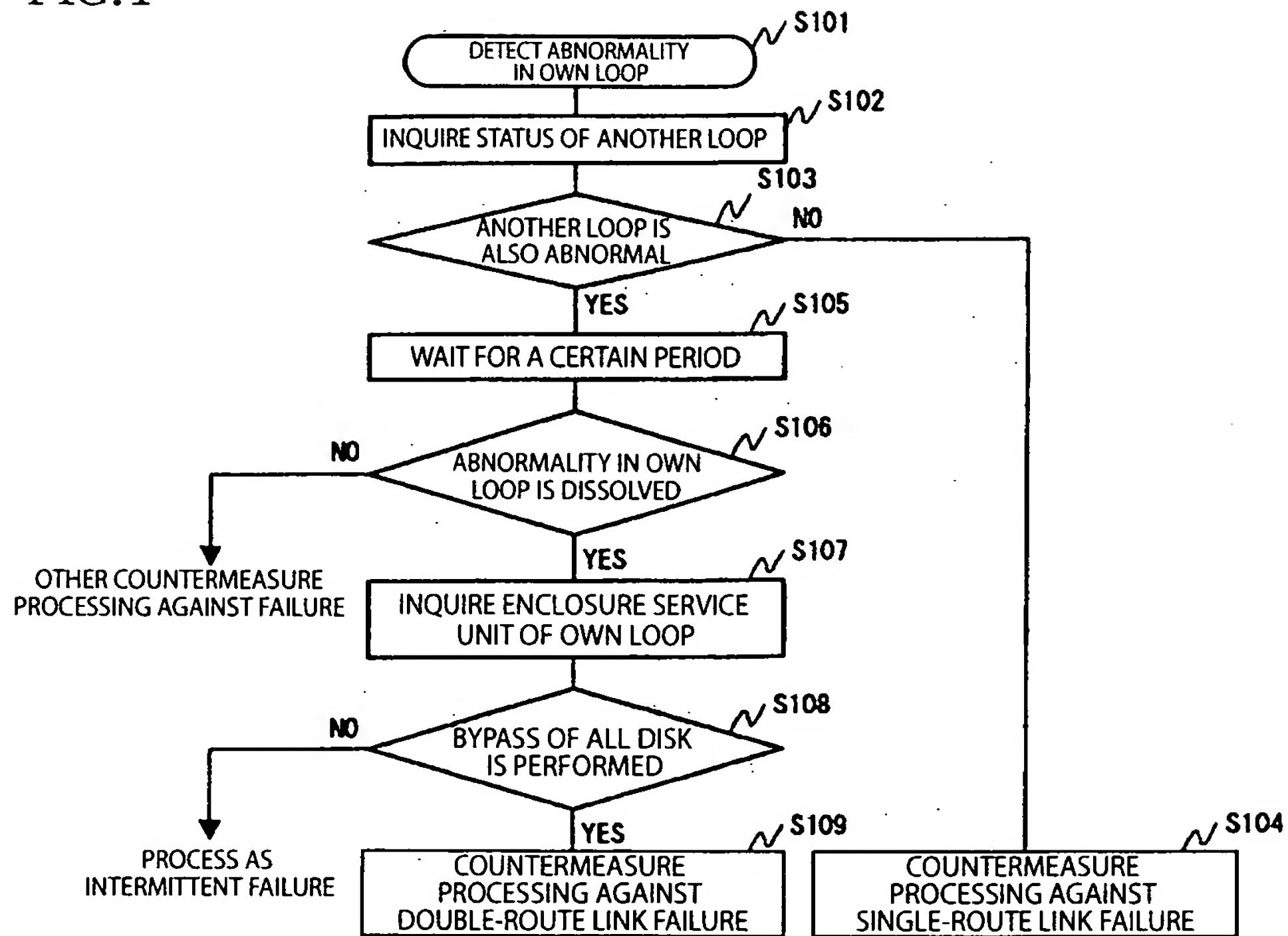


FIG.5

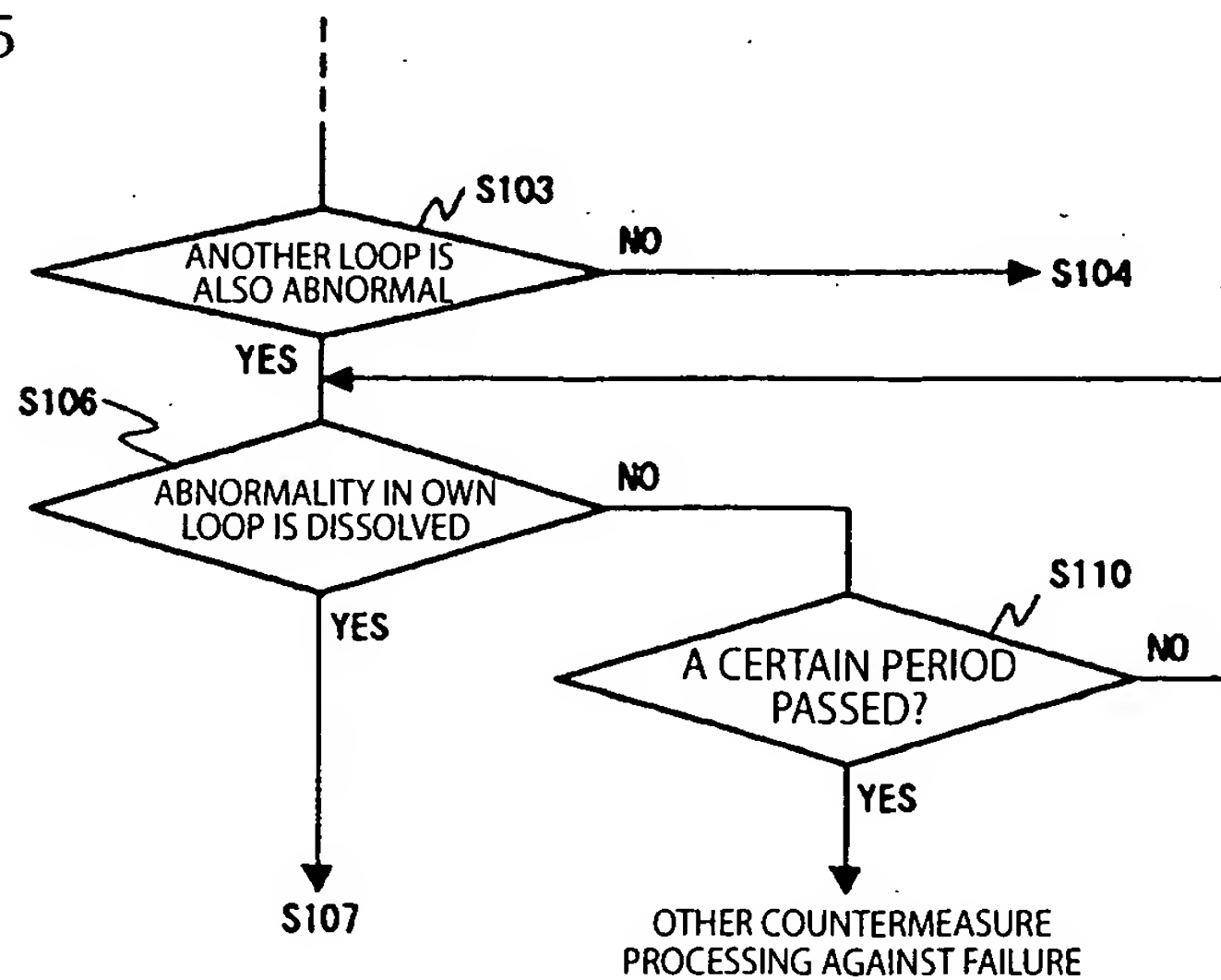


FIG.6

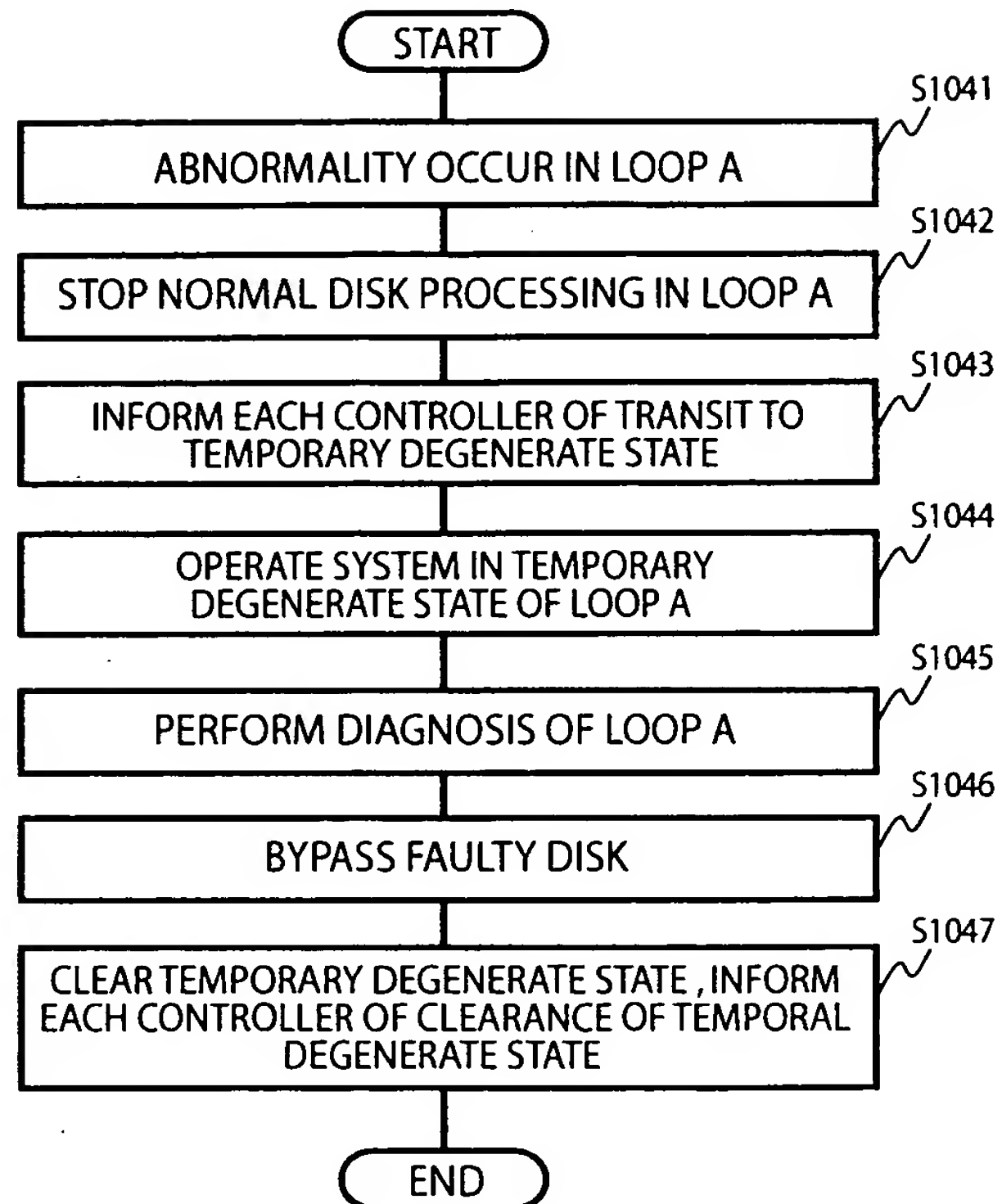


FIG.7

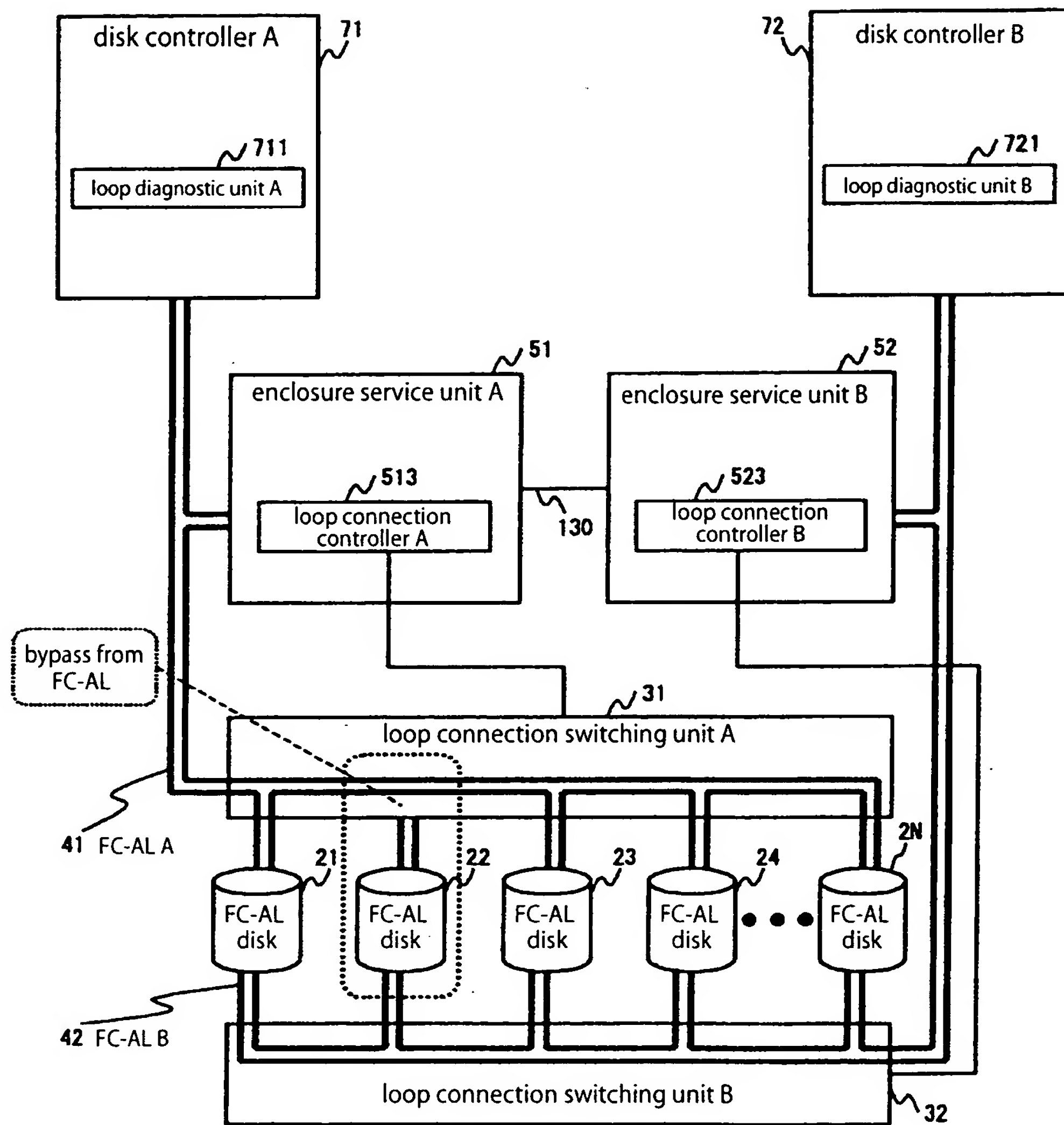


FIG.8

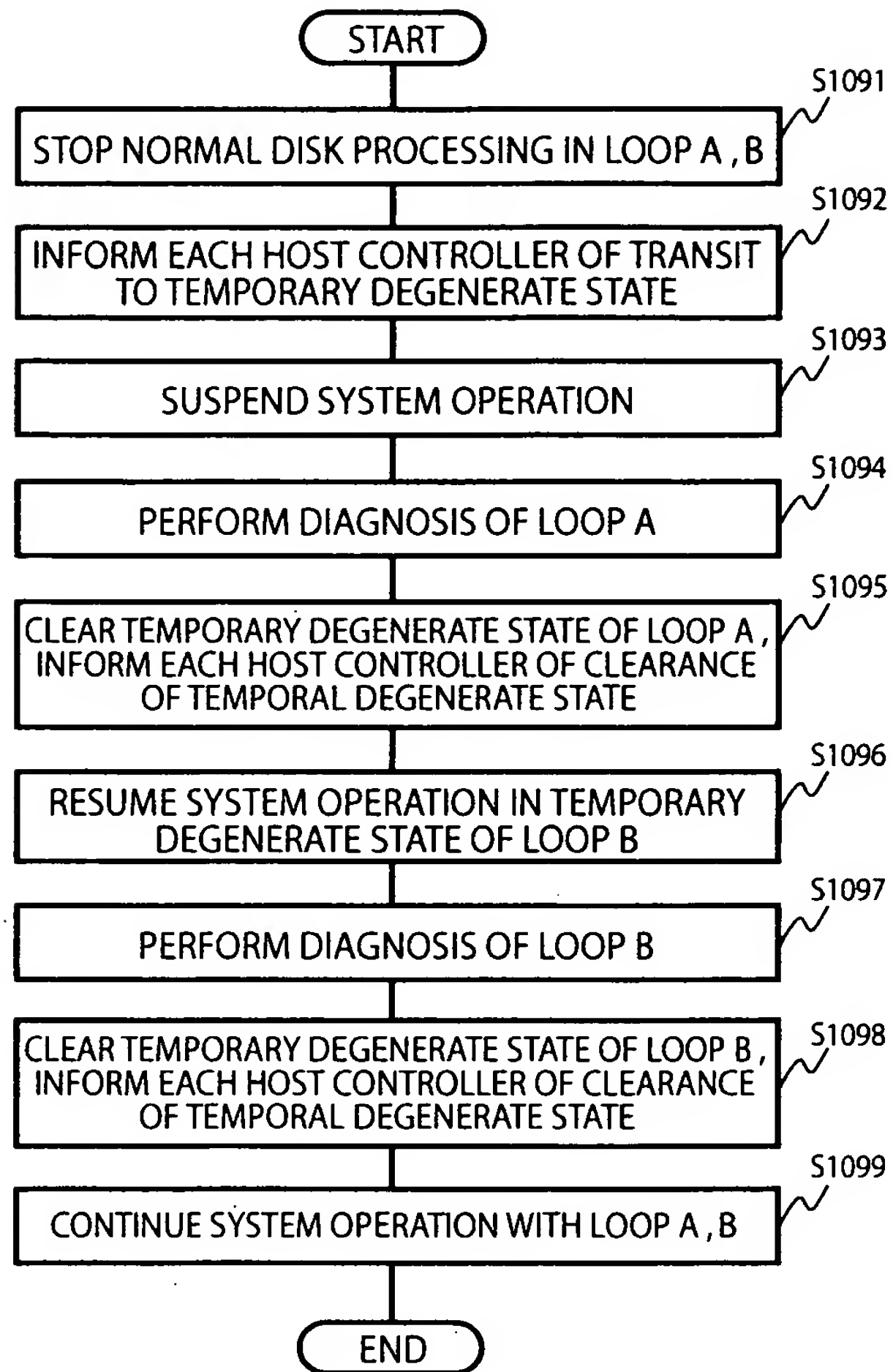


FIG.9

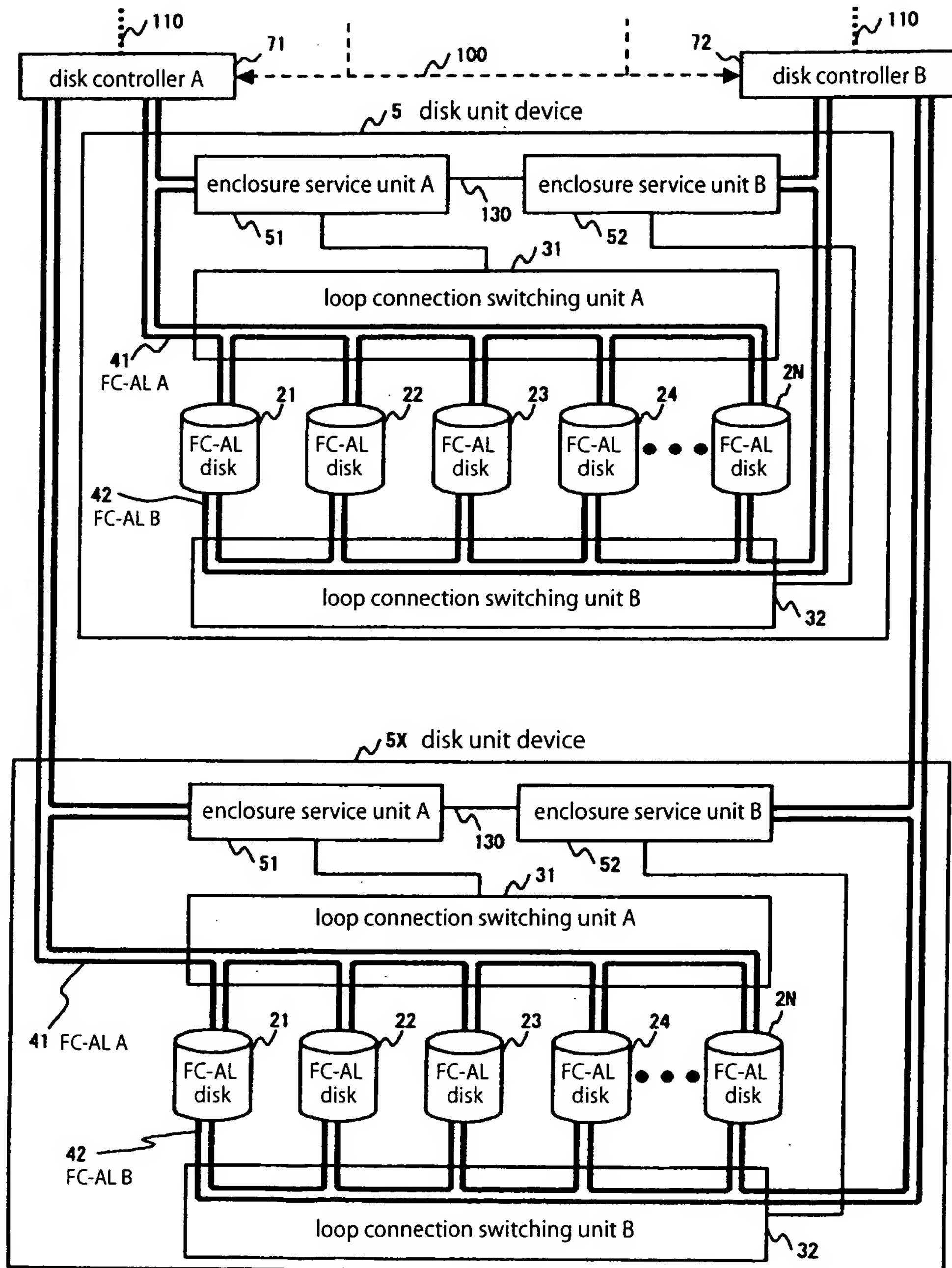




FIG.10

